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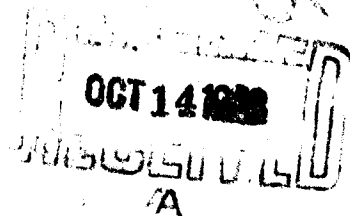
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DEPARTMENT OF THE ARMY  
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## THE HABITAT IN THE LIGHT OF PLANT PROTECTION

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Very early in the history of agriculture man has noticed that the extent to which plant diseases and parasites occur varies with the habitats, and that the yield of certain crops grown on these different habitats is endangered by these damage-causing agents to a greater or lesser extent. In the case of one-crop agriculture these dangers will appear sooner or later. This observation very early determined the course of action adopted by the farmer and gave rise not only to the form of agriculture in which different parcels of land are assigned to different crops but also to the introduction of crop rotation and other agricultural practices. A decrease in yield caused by parasites has been cited by certain historians and sociologists as one of the causes of broad population shifts and political and sociological development during past centuries. Sufficient examples are available from the last decades to show that certain plans aiming at carrying out a change-over in agriculture have often been prematurely limited by the increased occurrence of such damages, when the measures to be carried out involved habitats exposed to these dangers. This possibility imposes on the agricultural planner -- whether he is concerned with small or larger areas -- the task of characterizing the available habitats also from the point of view of the dangers presented by plant diseases and parasites, or in practical terms, to take into consideration, first, any possible risks to which these habitats may be exposed.

However, the scientific characterization of the habitat from the point of view of plant protection cannot be based on very much more evidence than is available to the farmer who has accumulated certain experiences relating to his region, his locality and to individual fields. We can express these experiences in a form that is more accessible to further reflections and calculations only by assigning a certain "probability

of damage" as a characteristic index to the individual habitat, and by taking this index into consideration in our reflections and calculations. However, in view of the fact that such an index must be determined separately for each crop and for all significant damages incurred by this crop on the given habitat, it would be necessary to add to the large number of habitat characteristics which have been presented today in the various papers perhaps an equally large collection of additional data. To what extent this procedure would be feasible in individual cases will not be discussed in the present paper.

However, the question arises as to whether this current probability of damage which describes the specific situations could not be determined indirectly from the rest of the habitat characteristics, from the magnitudes of the ecological habitat parameters; the use of such a procedure would obviously be necessary during the planning of more extensive transformations within the agricultural plant, when we must determine the probability of future damage without being able to rely on experience, i.e., when we must evaluate the potential damages caused by diseases or parasites, damages which may act as a limiting factor during the extension of a given crop or the introduction of a new crop.

Through a collaboration between the plant-protection research worker and the meteorologist, this task may be carried out with a relatively high prediction probability on the basis of climatic data for larger areas, as is shown by numerous data relating to the delimitation of main damage- and mass-transfer regions, as well as by cartographic representations relating to the possibility of the settling of certain damage-causing agents whose importation into the region under consideration is to be feared (e.g., in the case of the Japanese beetle).

However -- and this seems to be the main problem today -- if we want to make finer distinctions between the probability of damage in two agricultural plants within a given region, or, what is also interesting sometimes, in two plots situated within the same agricultural plant, then, if at first we neglect the properties of the soil and take into consideration only the climate, we find that the climatic data of the local meteorological station no longer represent a useful measure. In this case we are dependent on the climate of the farm, but even from this climate we must elaborate data that are more comprehensive than are available to the farmer or agriculturist who in most cases can orient himself on the basis of medium-range average values. This is so since the question of whether damage-inflicting fungus will settle in a farm and then develop further in a dangerous manner depends on the course of the decisive weather conditions over a shorter period of time and on the frequency and distribution of certain specific combinations of circumstances over a longer or shorter period of time. A simple and well-known example is offered by the so-called "phytophthora weather," a specific constellation of weather conditions lasting two days, which determines whether the disease known as potato rot will spread quickly. Actually the meteorologist would be able to predict these data over a short-range period. Without going into certain interesting details

at this point, we shall state that a weather situation such as this can become effective, i.e., significant in the sense of the probability of damage, only under the following two conditions:

1. The fungus can take advantage of the chance for further spreading only if, since the previous wave of infection, it has grown and become strengthened to such a point that it is ready for new fructification.

2. When the potato plant is not in one of its development stages, the initiation of a successful new infection is considerably impeded.

Without going into the possible significance of additional factors, we shall stress that not only does the course of the weather over relatively short periods of time acquire a decisive importance in this case, but the coincidence of a specific weather situation with specific biological conditions in the damage-producing agent and the host -- i.e., a not readily definable coincidence relationship -- is also of major significance. Anyone interested in producing an epidemic artificially, as is done, e.g., during the breeding of plants in order to imbue them with resistance to certain infections, knows the importance of this coincidence. When the phytophthora weather sets in two days too early and does not recur later on, then a phytophthora epidemic which has had a good beginning will be arrested for the vegetation period; if it sets in during a period in which the host plant, not yet resistant, inhibits any further development, then it will not be effective; finally, if it appears eight days too late, it delays the development of the epidemic perhaps to such an extent that the critical intensity of harmful attack desired for the selection is not attained. This may bring to mind the fact that even the differences between varieties must be taken sufficiently into consideration during the evaluation of the probability of damage, and they must be considered in a meaningful manner when arriving at practical conclusions. Our second example shows the importance of individual weather parameters. The migration of the pea-leaf-edge beetle which hinders the early development of the pea during the spring and which has its winter quarters in alfalfa- or clover fields, depends on the amount of sunshine during the critical autumn- and spring days: only when warmed by the rays of the sun can it cover the distance quickly by flying.

Thus, in order to deduce or even predict the probability of damage from climatic factors, we need a deeper insight into the course of the weather prevailing on the individual crops; however, we must also know the coincidence of specific weather constellations with certain critical periods in the life of the damage-producing agent and the host plants, regardless of whether we look upon the events taking place from the positive or the negative point of view.

With regard to harmful agents bound to the soil, which are of quite special interest to us today in connection with questions of crop rotation and similar problems such as root disease, smut fungus, Nematodes, etc., which occur at specific habitats and cultivated plots, certain characteristics of the soil, as determined by the soil scientist, sometimes give an

explanation for such occurrences. Sometimes a high probability of damage at more or less narrowly circumscribed places calls attention to differences in the subsoil. Apart from relatively unchangeable soil characteristics, those which are changed by the cultivation play a considerably role; we must constantly find new avenues of approach to new problems. This applies for example to the root disease known as blackleg disease of the wheat, or more specifically root smut caused by *Ophiobolus graminis*, which formerly had been considered a disease of soils which are not too suitable for wheat growing. Yet during the last few years this disease has occurred more and more frequently on the best wheat soils. To explain this occurrence the information presently available is not sufficient; we assume that we have to do with a result of the changed soil-cultivation methods, perhaps in connection with soil compacting which on the one hand leads to a change in the sensitivity of the wheat roots and on the other hand and especially to a change in soil biology. A similar conclusion seems to be indicated as a result of our observations carried out for many years on the root diseases of the pea in the East-Frisian marshes. The concentration or survival of many harmful agents is determined by their ability to compete with other soil organisms, and the latter should be considered as useful agents and their growth enhanced through cultivation measures of all kinds.

If, however, certain crop rotation measures aiming at the prevention of a specific damage are carried out in a too one-sided manner, then certain new problems may arise:

Thus, e.g., the overly intensive introduction of oats into the crop rotation system for the prevention of root diseases of other principal kinds of cereals may be limited by the fact that on certain soils a one-sided rotation of cereal crops may considerably increase the probability of damage caused by cereal Nematodes.

Thus the flora and fauna of the soil are important characteristics of the habitat, considered from the point of view of plant protection; they are important not only in their static aspect but also in their dynamics, i.e., their reaction to other influences. These characteristics, however, are still quite unknown to us. It would be especially desirable to increase our knowledge of the micro-soil-biological characteristics of the habitat. This is easier said than done: the picture of the real conditions in the soil which is obtained by means of the classical method of microbiological soil analysis -- consisting in analyzing samples on a plate -- is hardly any better than if we were to try to obtain a picture of the sociological conditions prevailing in New York on the basis of an experiment -- if I may use the simile of a colleague which he presented in a related discussion -- consisting in reducing the city of New York to powder and then subjecting a few powder samples to spot checks. Only with time will the mutually supplementing use, by scientists, of various currently available methods yield, after much effort, the desired insight in this area and help us obtain a picture of the interplay between the soil organisms and their significance for the probability of damage. At any event, even in this direction the characterization of the habitat from the point of view of plant protection needs considerably more numerous and finer characteristics than soil dynamics and crop production.

So far we did not yet take into consideration that many of the factors which were briefly touched upon above act not only directly on the damage-causing agent but also in an indirect manner through the plants which for some agents is also a habitat. For example we know wheat varieties which, depending on the temperature, react to rust fungus in a highly variable, highly susceptible or fully resistant manner. The sensitivity of certain plant roots to secretly acting putrefactive agents greatly depends on the available phosphate in the soil. Many other examples oblige us to undertake an even more strongly differentiated examination of the habitat in its interplay with the crops grown.

From the point of view of plant protection the concept of habitat, as we have defined it today, is almost always too narrow when we consider the harmful agents attacking from above the ground. The primary contamination with spores of fungi or with flying insects which frequently carry viruses as well has its origin in areas that are located both near and far. Apart from the fact that the time and intensity of the flight is determined by the air movements which in this sense must be considered also as a habitat characteristic, often it is the proliferation or wintering of the agents at an entirely different place which determines the extent of danger presented to our habitat. The importance of intermediate hosts for rust fungus and aphids is generally known. Much less frequently does the farmer think of the importance of secondary hosts, of wintering places of harmful insects and similar factors whose absence or presence, proximity of remoteness also have an influence on the probability of damage. These factors are not limited to the immediate vicinity: they act over different distances. Their effect is, e.g., dependent on fine nuances -- whose nature is as yet unknown to us -- of the mood or behavior of the damaging insects, factors which in turn are regulated by the environment. For lack of time we cannot go into this question in greater detail. It is precisely in the case of the harmful insects that the situation becomes even more complicated by the fact that parasites and animals which prey on harmful insects exert a secondary effect on the probability of damage and which, in turn, depend on the immediate environment or more distant environment of the habitat, as we have described above. Thus, e.g., the syrphus fly which has a decisive influence on the proliferation of aphids in the area near Goettingen, can fly over a distance of several km every day, so that quite far from the habitat under consideration, -- i.e., from the flowers on the field in question which serve as a source of nutrition for the fly -- the aphid-accommodating bushes which act as a source of food for the larvae must be included in the habitat concept, and the factors prevailing in this distant area may exert an indirect effect on the contamination of the habitat under consideration.

All this may suffice to show that from the point of view of plant protection the habitat is certainly not delimited in a strict sense, since as we take into consideration the various harmful agents, the boundaries of the habitats must be taken as having different boundaries; likewise, the above discussion may have shown that in order to be able to determine the habitat factors and their effects which determine the probability of damage, it is necessary to carry out further, more comprehensive scientific work.

Why is it that today, more than ever before, the above-mentioned interrelations arouse such particular interest in the field of plant protection? Is it the scientific effort to get to know the working of Nature in greater detail that is the subject of this interest, or is it stimulated by certain questions of practical importance? The answer is that these concerns are motivated by these questions of practical importance, not so much because the more intensive methods of agriculture and one-sided utilization of the land increase the economic importance of the diseases and parasites, but primarily because during the last decade the strategy of plant protection has had to utilize, more than ever before, the possibilities inherent in Nature for the reduction of hazards. This is not to be considered as a new discovery: already the decree which established the German Biological Office (Biologische Reichsanstalt) defined, as one of the tasks, the search for natural biological counterforces against plant diseases in the widest sense. Indeed this method of approach was actually used, although at first an attempt was made to exclude the idea of damage-causing agents as much as possible. At the turn of the century the discovery of resistant varieties and the discovery of relatively simple possibilities to combine this resistance to disease with other valuable properties through planned breeding, seemed to be such a method of protection, at least against the most important fungus diseases. However the natural adverse selection of resistance-breaking species repeatedly pointed up certain limits which could be overcome only by means of unending efforts through the discovery of new resistance factors, often by crossing varieties and species. In many cases the question now arises as to whether, in the light of the results obtained, this method is still feasible from the economic point of view -- whether it is at all possible in this way to "kill" the disease-producing agents.

The great advance made by organic chemistry during and after the second world war has seemed to facilitate the fight against most damage-producing agents, including the insects which were hardly included in the classic resistance breeding; the organic chemical industry offered preparations which, in my opinion, are still among the cheapest and most effective agents considered from the plant-economic point of view; this is so because it is only after their use that the effect of other measures is liberated. However, analogously to the adverse selection of resistance-breaking species, the constantly increasing and many-sided use of such agents has had the effect of introducing disease-resistant varieties, of leading to an adverse selection among the parasites, of causing an increase in the proportion of individuals which are at least so resistant to specific chemicals -- and in certain cases against all such agents -- that the use of the chemical method is no longer worthwhile; in addition as you all know, certain serious hygienic considerations have arisen which militate against the increasingly more intensive use of chemicals, even though in certain cases these considerations are somewhat exaggerated. I shall mention this only parenthetically, since the topic is now the object of wide discussions and is not directly related to the problems treated in this paper.

The strategy of the total elimination of damage-causing agents is frustrated by the natural selection of resistance-breaking or biocide-resistant breeds. This brings up the question as to whether our aims were not set too high, whether it would not be more correct and economical to adopt a more modest objective and to try merely to limit the dangerous proliferation of the disease-causing agents to such an extent that the economically evaluated possibility of damage is minimized, doing this by rationally combining all available possibilities, even those that are only partially effective, in order to reduce the probability of damage. Such measures include the agricultural possibilities for the suppression of harmful agents or for the strengthening of the host plants, measures aiming at the sparing and enhancement of useful organisms which suppress harmful agents; the limitation and rational execution of chemical measures in cases where all other possibilities fail.

Further possibilities in the struggle against damaging insects are offered by the self-destruction experiments which are being carried out here in Munich, i.e., the use of artificially sterilized individuals for the elimination of the natural fertility of a damage-causing population.

The rational combination of all these methods with the inclusion of the biological attack in the stricter sense, i.e., the purposive introduction of parasites and enemies of the harmful agents in order to increase the intensity of the natural counterforces, is the content of the strategy of plant protection known all over the world by the term "integrated plant protection."

The use of these possibilities which -- and we want to stress this particularly -- are in many cases not yet ready for practical application is, today, the aim of plant-protection research and, to the extent that they have been tried out, also of plant-protection consultants not only in our country but all over the world, including the developing countries which, partly for reasons other than are operative in Germany, have decided to embark on a course of integrated plant protection and biological attack.

Most of the methods just mentioned do not lead to the elimination of the damage-producing agents. All that we expect is that the rational combination of these methods will maintain the proliferation of the harmful agents on a level which rules out the occurrence of the agricultural damages under consideration. To evaluate the success of such an integrated plant protection we must know the economically acceptable limits of an attack caused by parasites -- as has recently been clearly brought out during a symposium of the FAO in Rome -- and also find out how these limits may be changed through the coincidence of the most varied causes of damage: this is so because what the practicing farmer demands from the science of plant protection is, first of all, the prevention of economic losses caused by these harmful agents, regardless of the method employed. In order to be able to choose the right method we must know these limits: this makes it necessary that the science of plant protection ask the related disciplines: Where are these limits which, when exceeded, pose the threat of a serious damage under specific circumstances and under the effect of a specific combination of harmful attacks which varies from region to region?

And with this question our discussion again reverts to the central thesis of this meeting, namely that the conditions for the proliferation of damage-causing agents vary from habitat to habitat. To be able to make use of this situation and to advise our clients to undertake additional rational measures, we must know the special characteristics of the habitat and the effective forces acting on this habitat. Only then shall we find the ideal combination of measures which will spare the crop as much as possible and which are in harmony both with the farmer's desire to ensure his crop yield and with the consumer's demand for safety.

Such a strategy requires two things:

1. A much more intensive study of the correlations between the intensity of occurrence of parasites and the reduction in yield, as well as of the influence of the environment on this relationship, i.e., a more accurate study of the habitat.

2. This ideal agricultural method, this ideal plant protection, which must be adopted to the habitat and the changing conditions from year to year, requires an intensification of the advisory services offered to farmers. Here I have talked as if the attainment of this goal were an easy task. Actually it is necessary to determine the above-mentioned relationship of coincidence between the weather conditions, the attacks of parasites and the damage produced for each parasite, each crop, each habitat and for each year, and perhaps it is necessary to consider these problems from an entirely practical point of view, in order to be able to arrive at a decision as to whether a chemical measure should be carried out on a given farm and at a given time. To say that such a measure should be carried out is an easy decision: we can orient ourselves on the basis of almanachs, habits or our neighbors. On the other hand a negative answer requires responsibility and can seldom be arrived at on the basis of models, but only after the rational evaluation of empirical data, because the introduction of new production methods may also bring to light new problems.

The individual farmer can assume the responsibility for such decisions only to a partial extent. In the future he will need more help from trained advisers who are not loaded down with other tasks.

The value and effect of such counseling and the progress of the research on which it is based will be in direct proportion to the extent to which it can be supported by the data of the various branches of the agricultural sciences. We ask you to think along with us in regard to the problems just outlined and assist us in the framework of collective research to which we have frequently referred today, in order to provide us, in addition to the biological data of damage-causing agents and the investigations of their effect, also with the corresponding agricultural and economic data which must guide our considerations not only for the single case, the single plot of land or a single year but also for rotated crops and for specific agricultural systems. It may happen that as part of this strategy we shall accept a small loss in the yield of one of the rotated

crops if in this way the yield of the whole crop may be increased at all; however, this problem requires further intensive study.

I hope that during the short time at my disposal I was able to stimulate you without succumbing to the danger of burdening you with too much material from the broad realm of observed and nonobserved phenomena.